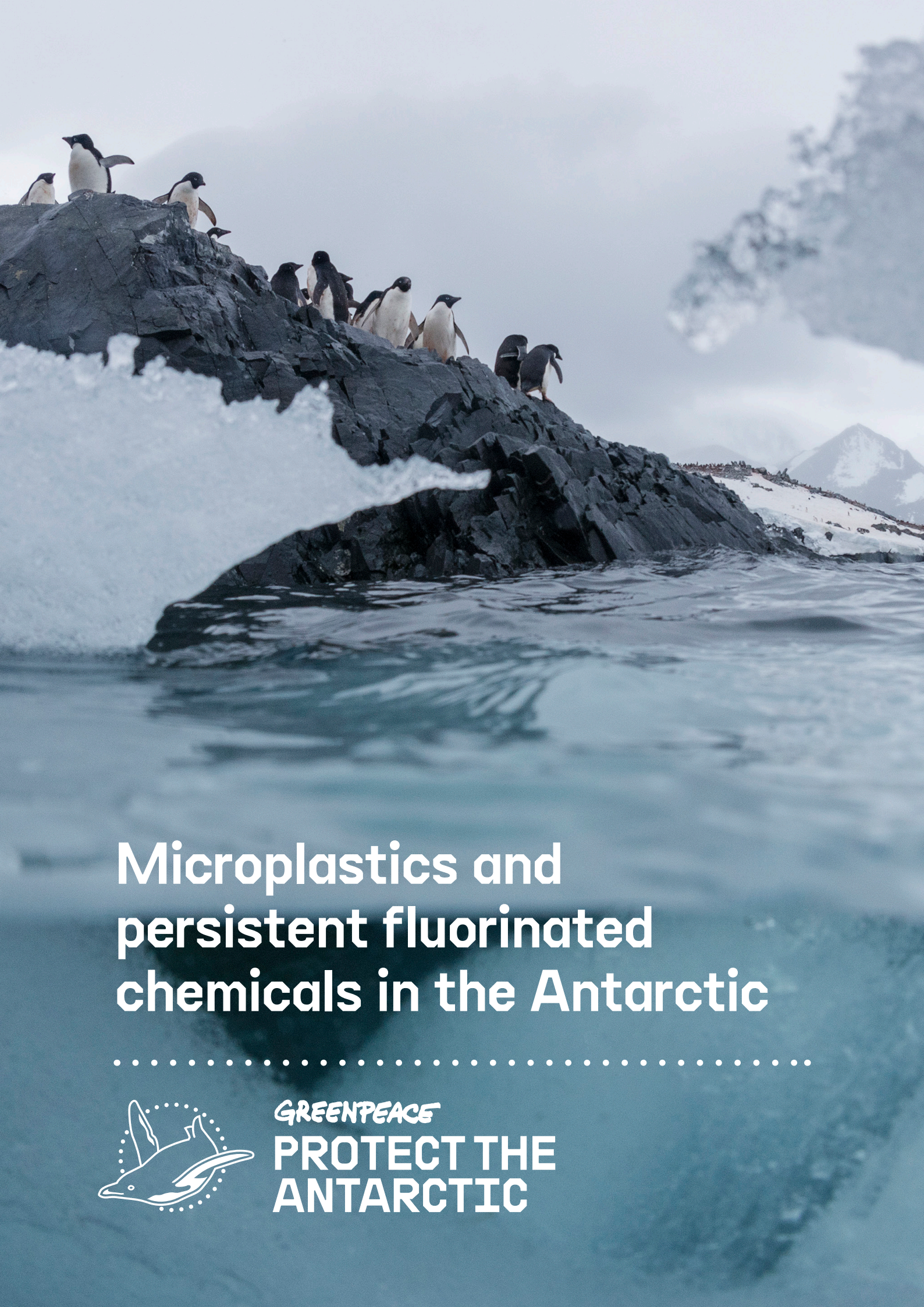

Microplastics and persistent fluorinated chemicals in the Antarctic

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Aerial view near the Weddell Sea in the Antarctic
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Executive Summary

In early 2018, Greenpeace undertook an expedition to the Antarctic to carry out scientific research, including seabed submarine dives exploring little-known benthic ecosystems and sampling for microplastics and persistent chemicals, in order to learn more about biodiversity and pollution in this remote area.[1]

This briefing presents the findings of the sea-surface water samples and manta trawl net samples taken to investigate the presence of microplastics in Antarctic waters, and the snow samples taken to analyse for the persistent and hazardous chemicals, per- and polyfluorinated alkylated substances (PFAS).

The samples show that even the most remote and pristine habitats of the Antarctic are contaminated with microplastic waste and persistent hazardous chemicals.

Microplastics:

- Seven of the eight seawater samples that were tested contained microplastics, with at least one microplastic fibre per litre. With limited data available on the presence of microplastics in Antarctic waters, these significant findings provide a valuable addition to datasets, confirming the presence of contamination in the region.
- In addition, nine samples were taken using a manta trawl and analysed for microplastics. Microplastic fragments were detected in two samples.

Chemicals:

- Detectable concentrations of PFASs were found in freshly fallen snow at nearly all of the sites where samples for PFAS analysis were taken. A total of nine snow samples and six water samples were taken.[2]
- PFASs are a group of chemicals widely used in industrial processes and consumer products and have been linked to reproductive and developmental issues in wildlife. The snow samples gathered included freshly fallen snow, suggesting some of the hazardous chemicals were atmospheric and not from a local source. The chemicals are persistent and degrade in nature very slowly.

Greenpeace's Antarctic investigations add valuable new data to the scientific investigation of contamination in the Antarctic region. The findings confirm the presence of persistent microplastics and hazardous and persistent chemicals (PFASs) in remote regions around the Antarctic Peninsula and the Bransfield Strait, including in areas that are being considered for protection because of their importance for wildlife. The findings for microplastics are within the range of other scientific studies on seawater in remote regions. Given that there is little data for microplastics or microfibres in Antarctic waters these investigations provide new information on the status of contamination in the region.

The Antarctic Circumpolar Current acts as a natural barrier encircling Antarctica, with a minimal exchange of seawater from North to South. Considering the many uncertainties involved in such investigations, the findings suggest that the marine transport of microplastics is not completely restricted by this barrier.

The findings of PFASs in snow confirm the results of previous Greenpeace expeditions to remote areas in Asia, Europe and South America. Once they are released, PFASs are spread globally by long distance transport through the atmosphere and are deposited as snow in all remote regions.

Both microplastics and PFASs are man-made materials with a wide range of uses that are contaminating the planet's water bodies and potentially harming aquatic organisms.

Sampling for PFASs in snow and water took place during Greenpeace's expedition to the Antarctic, in January, February and March 2018. As well as the nine snow samples, six water samples were taken. Water samples for microplastics were collected in February.

Marine biologists carrying a box of snow samples
© Christian Åslund / Greenpeace

Sampling Locations

January, PFASs:

The locations visited in January were Hope Bay on the Trinity Peninsula, Kinnes Cove on Joinville Island (both flanking the Antarctic sound) and Lecointe Island off Brabant Island (Gerlache Strait). Two samples of snow and two samples of water were collected at each location. The samples were analysed for PFASs.

February, PFASs and microplastics:

In February, water samples for PFASs were collected at Maxwell Bay between King George Island and Nelson Island (Bransfield Strait). Seawater samples for microplastics analysis were collected in the same location. Samples were also taken at Cuverville Island in the Gerlache Strait and Yankee Harbour on Greenwich Island in Bransfield Strait. These samples were analysed for microplastics.

March, PFASs:

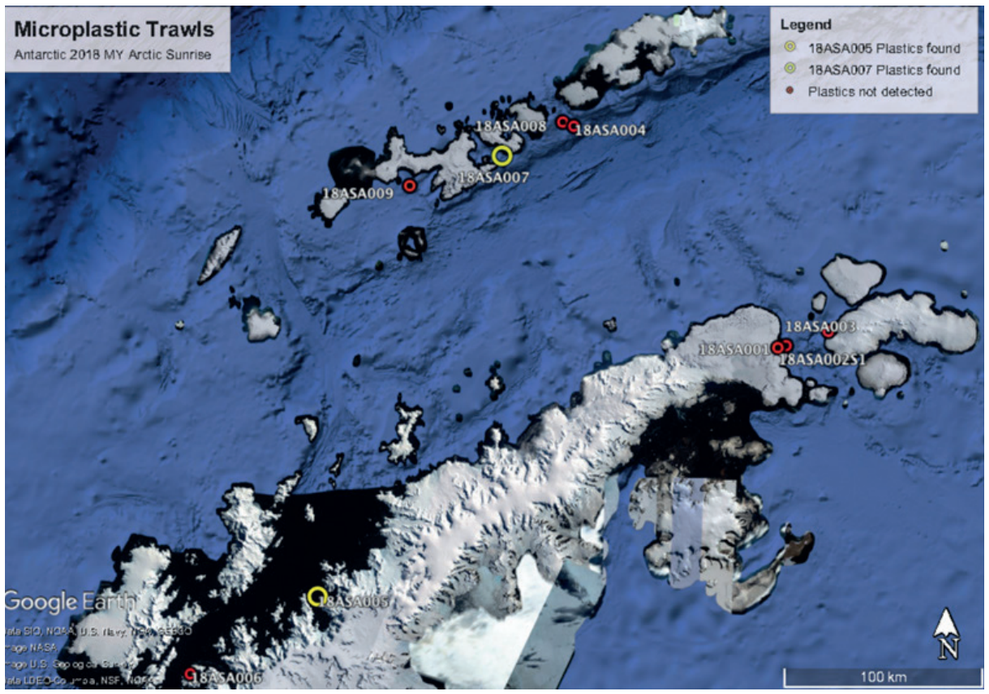
In March, snow samples were taken in Discovery Bay on Greenwich Island (Bransfield Strait). Samples were analysed for PFASs.

Some of the samples were collected from locations remote from potential local sources, e.g. Joinville Island and Lecointe Island. Other samples were collected in the vicinity of local sources with scientists visiting or tourist traffic, for example at King George Island or Greenwich Island.

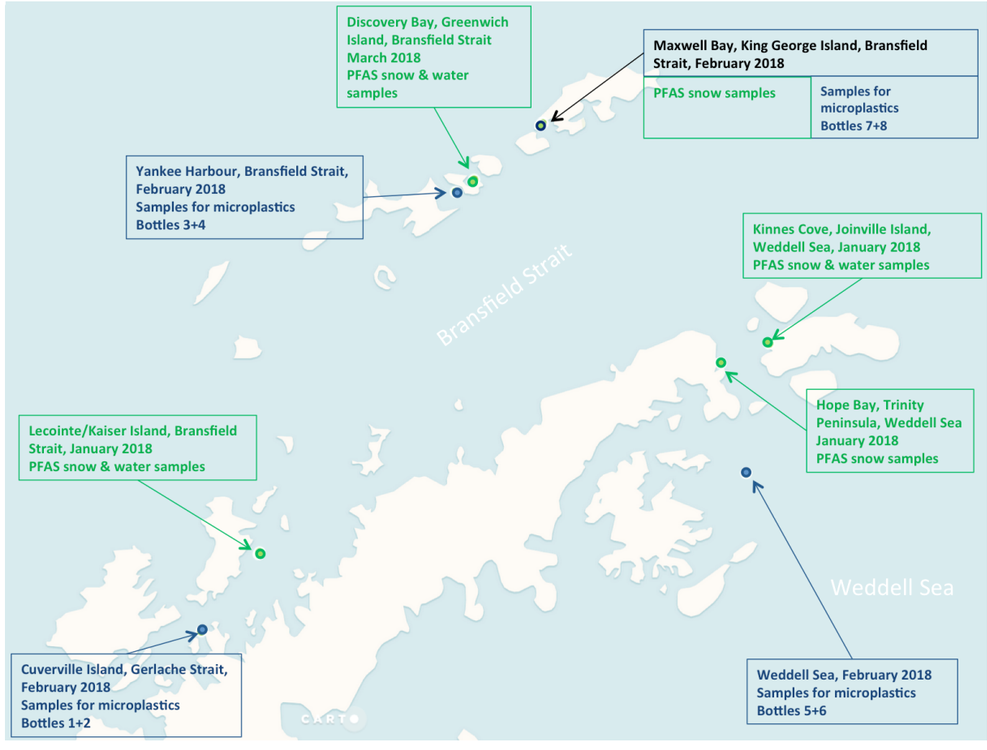
Overall nine snow samples and six water samples were analysed for PFASs. Eight seawater samples were analysed for microplastics.

Microplastic sampling in Antarctic waters from aboard the Arctic Sunrise
© Christian Åslund / Greenpeace

The sample locations



The nine manta trawl locations



Microplastics: The Problem

Much of the recent focus on marine plastic pollution has been on the larger, more immediately recognisable pieces of plastic litter that enter the ocean – between 4.8 and 12.7 million tonnes every year.[3] However, there are growing concerns about microplastics – commonly defined as pieces of plastic with a diameter of 5mm or less[4] – which have potentially negative impacts on marine species, including seabirds and filter-feeding sharks. This is both because of the direct physical effects of the plastics when they are ingested by marine animals and because of the mixture of potentially hazardous chemical additives and contaminants they can carry. Microplastics include:

- Fragments of larger plastic items in the ocean that have broken into smaller pieces by natural processes such as waves, sediment abrasion, and degradation in sunlight[5].
- Plastic particles deliberately manufactured to be in this size range, such as microbeads used in cosmetics and personal care products.
- Microplastic fragments from land-based sources such as tyres, or fibres from synthetic clothes, which are released into wastewater systems when consumers wash them.

While larger pieces of plastic are a very obvious symptom of ocean pollution, microplastics are a far less visible part of the same problem, and arguably even more difficult to measure and address. The source of the plastic can be onshore and offshore, including from wastewater discharges from land and at sea, urban run-off, windblown litter, and even lost or abandoned fishing gear.

Because of their synthetic nature and their propensity to adsorb or attract chemicals from seawater on to their surfaces, microplastics can also carry substantial concentrations of a range of chemical additives and contaminants,[6] contributing to the exposure of marine species to hazardous chemicals.[7]

Microplastics have previously been reported in the guts or other tissues of a wide range of marine species, including fish and shellfish,[8] seabirds that feed on plankton[9], cetaceans such as whales and dolphins,[10] and plankton that form the base of marine food web.[11] The exact nature and scale of the threats that microplastics pose to marine ecosystems have not yet been fully determined.[12] However, it is already clear that the tendency for microplastics in seawater to be taken in along with food particles by marine organisms such as filter-feeding and foraging species can have physiological and behavioural consequences. This includes inflammation of gut and other tissues, impacts on energy balance and growth rates and changes in feeding behaviour and efficiency.[13]

Antarctica is not associated with the scale of plastic waste plaguing other parts of the world, however, microplastic pollution has previously been found in the Southern Ocean. Relatively dense concentrations of microplastics in deep-sea sediments and surface waters similar to those found in Northern Hemisphere oceans have been discovered at two out of five stations around Antarctica that were surveyed.[14] These and similar findings raise concern about the widespread nature of marine plastic pollution and the possibility of krill ingesting microplastics and so entering the food chain.[15]

Microplastics: Key Findings

Microplastics from seawater samples

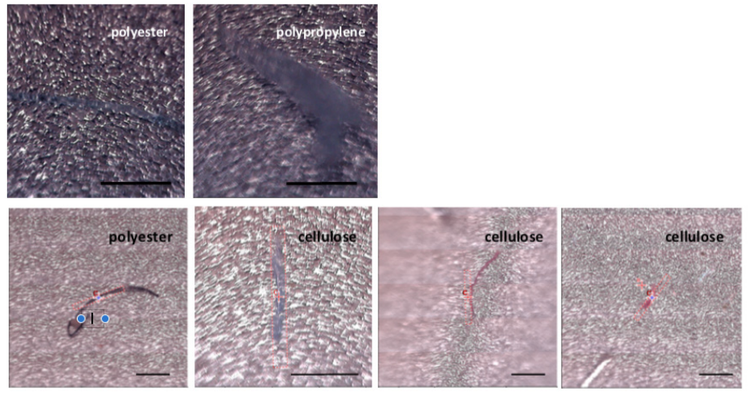
A total of 8 x 2.5 litre samples of surface water were collected as duplicates from 4 separate locations in Antarctic waters in February 2018 (ANT18001-8). For analysis, 1 litre of the 2.5 litres was filtered through a silver filter with a pore size of 5 µm. Possible microplastics/ microfibres retained by the filters were initially identified under a dissecting microscope and subsequently analysed using FT-IR microscopy to try to identify the material. Two laboratory blank samples were prepared under the same conditions to control for airborne fibre contamination (filtering an equivalent volume of deionised water), but none was found. For further details of the methodology see Annex 1.

All 8 samples (4 location duplicates) were found to contain at least one man-made fibre, at densities of between 0.8 and 5.6 fibres per litre, and with at least one of those fibres confirmed by FT-IR as microplastic in 7 of the 8 samples. Microplastic fibres identified included:

- Polyester (4 fibres across 3 samples, either black, blue or transparent).
- Polypropylene (1 transparent fibre in 1 sample), Nylon (4 fibres across 4 samples, again either black, blue or transparent).
- PTFE (2 dark blue branched fibres across 2 samples).
- A form of acetate (1 transparent fibre in 1 sample).

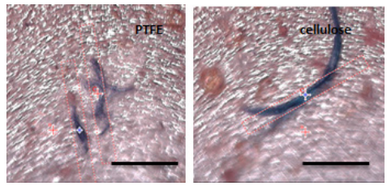
Sample ANT18001-2

Position: 64°38.496 S;
062°36.910 W
Date: 15/02/18
Time of sampling: 1839hrs GMT
Finding: ANT18001 2.0 fibres/litre;
ANT18002 3.6 fibres/litre



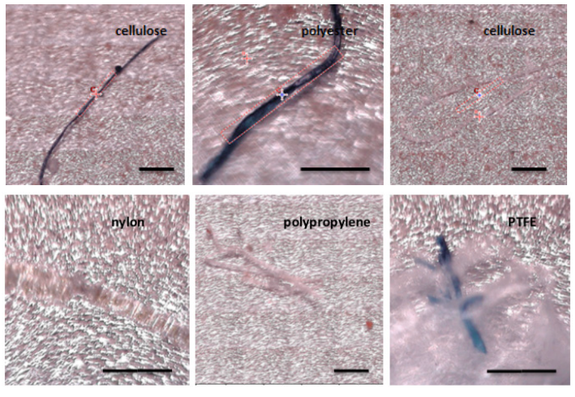
Sample ANT18003-4

Position: 62°32.073 S;
059°51.377 W (Yankee Harbour)
Date: 18/02/18
Time of sampling: 1412hrs GMT
Finding: ANT18003 4.0 fibres/ litre; ANT18004 0.8 fibres/litre



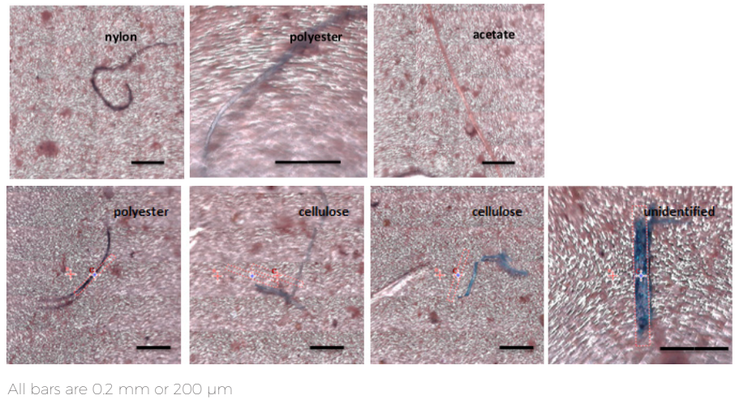
Sample ANT18005-6

Position: 63°54.053 S;
056°42.496 W (Weddell Sea)
Date: 22/02/18
Time of sampling: 2215hrs GMT
Finding: ANT18005 2.8 fibres/ litre; ANT18006 3.2 fibres/litre



Sample ANT18007-8

Position: 62°12.145 S;
058°56.488 W (King George Island)
Date: 26/02/18
Time of sampling: 1856hrs GMT
Finding: ANT18007 5.6 fibres/litre;
ANT18008 2.8 fibres/litre



All bars are 0.2 mm or 200 µm

In addition, sample ANT18002 contained a small, irregular fragment of pale blue polypropylene, approximately 300 µm in diameter. Sample ANT18008 contained a highly transparent fibre showing an infrared (FT-IR) spectrum consistent with that of glass fibre, possibly arising from degradation of a fibre-reinforced plastic material.

All samples contained one or more fibres identified under FT-IR microscopy as cellulose, despite being quite strongly coloured (blue or red) in most cases. In many samples, these formed the majority of fibres present. Although it cannot be ruled out that these cellulose fibres are of natural, plant-derived origin, their colour strongly suggests that these are fibres of heavily processed or man-made cellulose products, such as rayon or viscose, or perhaps cotton.

A number of other fibres and fragments found on the filters were determined by FT-IR microscopy to be of natural origin, including irregular, transparent cellulose fibres, chitin fragments and inorganic matter. A minority of fibres could not be identified to sufficient match quality against library spectra.

The photomicrographs presented below illustrate the verified or potential man-made microfibres found in the samples.

Microplastics from manta trawl samples

Nine samples were taken using a manta trawl net at seven locations. Two different manta trawl nets were used. The first had an aperture of 0.185m x 0.600m and the second was slightly larger at 0.155m x 0.870m (see Annex 3). In two of the samples a fragment of microplastic was found, one in each type of net. The microplastics were identified as high-density polyethylene (18ASA005) and polypropylene (18ASA007).

The MY Arctic Sunrise heading south to the Weddell Sea
© Daniel Beltra / Greenpeace

PFASs: The Problem

In a recent report Greenpeace found traces of per- and polyfluorinated alkylated substances (PFASs – also referred to as PFCs) in snow and water samples from eight remote mountainous areas;[16] they were present in the snow that fell in the winter of 2014/2015, as well as in water from mountain lakes where these substances had accumulated over several years.

PFASs are widely used in many industrial processes and consumer products, and are well known for their use by the outdoor apparel industry in waterproof and dirt-repellent finishes. PFASs do not occur naturally, they are persistent and degrade very slowly, or possibly not at all; some may last indefinitely in the environment.[17] Once released into the environment they are dispersed over the entire globe.

The long range transport of some PFASs to remote areas has been studied scientifically for several years. In particular, certain PFAS compounds - such as the long chained perfluorinated alkylate acid PFOA or the sulfonate PFOS that are known to have toxic properties - are commonly found in snow and water.

Studies discuss three possible ways that PFAS are distributed in the environment.

- Some PFASs can bind to suspended particulate matter which is transported through the atmosphere and washed out and deposited in rain and snow.
- Volatile PFAS compounds such as polyfluorinated fluorotelomer alcohol (FTOH) and sulfonates can be transported in the atmosphere over long distances. They are called precursor substances, as during their transport they are subject to atmospheric oxidation, transforming them into persistent PFASs such as PFOA, which can then be deposited in high mountains or cold regions such as the Antarctic, for example.
- Finally, ocean currents may also play an important role by transporting PFASs globally, for example to the Arctic and Antarctic.

Certain PFASs can then accumulate in living organisms, such as the livers of polar bears in the Arctic. First introduced in the 1950s, PFASs have since been found everywhere from foetal cord blood to breast milk as well as in wilderness areas. There is evidence from animal data that some PFASs cause harm to reproduction, promote the growth of tumours and affect the hormone system.[18] In 2015 more than 200 scientists signed the Madrid Statement calling for certain PFCs to be phased out from non-essential use.[19]

Non-PFAS substitutes are widely available for clothing products and already used by many outdoor brands.[20]

PFASs: Key Findings

The results show clearly that PFASs are detected in snow even in this remote region of the Antarctic, with some samples taken at locations without potential local sources of PFASs. We found detectable PFAS concentrations in freshly fallen snow at nearly all of the sites we visited. The following discussion only considers the PFASs in samples with significant concentrations.[21]

Water samples were also taken but the results are not included here due to the possibility of contamination for two key samples.[22]

- The six PFAS compounds that were detected at least once in a significant concentration two or more times above the field blank were: PFBA, PFHxA, PFHpA, PFOA, PFUnA, PFHxS.
- In snow samples the sum of PFASs in this study ranges from the limit of quantification (LOQ) to 2.521 ng/L[23], with the highest concentrations found in snow from Maxwell Bay (King George Island) and Hope Bay (Trinity Peninsula). These findings are in the range of comparable studies which show 1.129-2.491 ng/L for snow from King George Island, Antarctica;[24] concentrations of 0.760–3.60 ng/L were found in freshly deposited snow from Coastal Livingston Island (Maritime Antarctica), near to a station, while in surface snow remote from the station the concentrations were 0.082-0.430 ng/L.[25]
- The most commonly detected chemical was PFOA, which was found in significant concentrations in 5 out of 9 snow samples. We found PFOA in more pristine sites such as Lecointe/Kaiser Island as well as in locations where there is science and tourist traffic such as King George Island and Hope Bay.
- The highest concentrations for PFOA in snow were found in Hope Bay/Trinity Peninsula (S-A.I.3. - 1.84ng/L[26]) and in Maxwell Bay/King George Island (S-B.II.3. - 1.86ng/L[27]).
- The C6 compound PFHxA was found in significant concentrations in snow samples from Hope Bay and Discovery Bay.
- Concentrations of PFHxA were significantly above the field blank, in 3 out of 9 snow samples ranging from between 0.053 - 0.075 ng/L[28] (Hope Bay) to 0.081ng/L[29] (Discovery Bay).

- In the snow sample from Maxwell Island (King George Island) PFHxS was detected in a concentration of 0.139ng/L.[30]

- PFBA (short chain C4 PFASs) was detected in a significant concentration in the snow sample from King George Island (S-B.II.3 - 0.325ng/L)[31] and in one snow sample from Discovery Bay (S-BII 3 0.468ng/L).[32]

The findings in snow samples are unlikely to be due to contamination from local inputs as a result of research activities and tourism in the local areas as the snow was freshly fallen.[33] The chemicals found in the snow could have been transported in the atmosphere over long distances, washed out by precipitation and then deposited in the Antarctic snow.

Discussion

Samples for PFAS analysis were taken in remote and pristine locations such as Joinville Island and Lecointe Island and in locations where research or tourism takes place, such as Hope Bay (Trinity Peninsula), which has a research station nearby, and Maxwell Bay in the Bransfield Strait, which has two research stations nearby and is regularly visited by scientists as well as tourists. Samples were also taken in Discovery Bay on Greenwich Island (Bransfield Strait), where trawlers, reefers and ships anchor; the government of Chile also runs a permanently inhabited station onshore. Either snow or water samples for PFASs analysis were taken at all of these locations.

Seawater samples for microplastics analysis were taken at Maxwell Bay and in two more remote locations; Cuverville Island in the Gerlache Strait and Yankee Harbour on Greenwich Island in Bransfield Strait.

The results for PFAS show generally higher levels in snow samples with local potential sources compared to Kinnes Cove (Joinville Island) and Lecointe on Kaiser Island.

Discussion on microplastics

Although microplastics have been identified as contaminants in all ocean areas, there remains remarkably little data available for the waters around Antarctica and the wider Southern Ocean.[34] In a recent review of the presence of microplastics in polar seas,[35] it is noted that most available data relates to the Arctic, in which the distribution and transport of microplastics has been more intensively studied to date. Other studies[36] call for greater research focus on Antarctica, accompanied by standardisation of methods to enable intercomparison of findings.

The presence of larger pieces of floating plastic litter in Antarctic waters was reported almost a decade ago.[37] More recent studies have documented the presence of microplastics in both shallow and deep-water sediments in the Weddell Sea[38] and in the Ross Sea[39] respectively. In the case of the Ross Sea, the sites sampled to date are located close to research stations in Terra Nova Bay and on King George Island respectively, and are thought to have been influenced at least in part by these local sources (through wastewater discharges, run-off and deposition of plastic particles from the air).

Two other studies[40] report the presence of microplastics in the water column of the Southern Ocean south of the Antarctic Circumpolar Current (ACC), though they investigated different locations using quite different methods and quantified microplastics in different size ranges. Based on a total of 5 manta net tows collected on a transect from Antarctica to Tasmania, the first of these studies[41] reported higher concentrations of microplastics (>350 µm) in waters south of the ACC (2 of the samples) than in those further north (3 samples), and suggested that, given the nature of the fragments identified, a majority were likely to have originated from sources outside Antarctica. These authors also concluded that concentrations at the two southern sites were of a similar order to those reported for other ocean areas (around 100,000 pieces per km^2).

By contrast, the second study[42] employed a high volume filtration system to sample at 18 stations in the Ross Sea, drawing between 600 and 2000 m^3 of seawater per sample from a depth of 5m below the surface. They reported average concentrations of microplastics on a volumetric basis, a more comparable basis to our study, but found an average of only 0.17 +/- 0.34 particles (in the size range > 60 µm) per m^3 of seawater, which the authors note is lower than reported for other ocean areas in which the same sub-surface sampling technique had been applied.

In comparison, the concentrations of microplastic and other man-made microfibres identified at the four stations sampled in our study were far higher, at 0.8-5.6 particles per litre (equivalent to 800-5600/m^3), with an average of 3.1 +/- 1.4 particles per litre. There are a number of possible reasons for this apparently large difference, including the small size range of the fibres that dominated the particles found in our study (with diameters considerably smaller than the 60 µm minimum applied by Cincinelli et al. (2017)) and the fact that we sampled the top 0.5 m of seawater only, which may be expected to accumulate higher concentrations of small buoyant fibres than in water at 5 m depth. It is also possible that the stations we sampled were simply more heavily contaminated with microplastics and other man-made fibres than those sampled by Cincinelli et al. (2017) in the Ross Sea, with contributions from more localised sources including, perhaps, discharges from ships and/or research stations. It has been noted[43] that, whereas shipping in Antarctica may be expected to make a relatively small contribution to overall levels of microplastic contamination in the Southern Ocean, such direct sources could be locally relevant.

Neither the concentrations of microplastics and other man-made fibres found in our samples, nor the frequency of types of polymer or other material identified, showed any clear patterns in relation to sampling location. Data for the duplicate samples collected at each station were quite different from each other, as may be expected for small, widely dispersed, discrete particles or fibres carried as passive contaminants of water motion. Every sample collected, even as replicates from a single sampling station, will inevitably be a unique snapshot of the distribution of microplastics. The variability in abundance and composition simply reflects the actual variability in the distribution of these contaminants in surface waters.

An interesting characteristic in our data is the relatively high proportion of cellulose-derived fibres in most samples, and exclusively in sample ANT18008. Similar findings have been reported by other authors for fibres in surface waters as well as in the guts of marine species; for example, one study reports[44] that around two thirds of all the particles found in their surface water samples along an extensive Atlantic transect were cellulose-based, identified by the authors as rayon. Although the possibility that some of those found are natural fibres cannot be ruled out, this seems unlikely for the majority given the very uniform diameter and intense colours of the majority of the cellulosic fibres identified, including blacks, blues and reds. It seems more likely that the majority are therefore fibres of processed cellulose-based material arising from man-made materials, though this clearly warrants further investigation.

Two sources of microplastic fibres in the ocean are likely to be their use in textiles and in fishing nets. Synthetic fibres, especially polyester, are widely used in textile products. For example, 60% of the material currently used in clothing is polyester, much of it in short life “fast fashion” items of clothing.[45] The fashion industry plans to nearly double its annual use of polyester by up to 76 million tonnes annual by 2030.[46]

The finding of two fragments of microplastics are also a cause for concern and are comparable to findings from other recent scientific studies.[47] The fragments of microplastics found in the manta trawl nets are the result of their widespread use, particularly as single use plastics in disposable consumer products.

Discussion on PFASs

PFAS do not occur naturally and should therefore not be found in remote wilderness regions. Nevertheless, they can travel around the world in the atmosphere, either as gas or bound to dust particles, until they are washed out in rain or snow. The fact that PFAS have been found (see footnote 21) in samples from nearly all visited locations taken is a cause for concern, showing that these persistent chemicals are contaminating even the most remote parts of the planet.

There have been only a few scientific studies on the occurrence of PFASs in snow and water from the Antarctic.[48]

Studies of snow from remote areas in Europe show that levels in snow from Sweden[49] were 0.0665 ng/l for PFOA while snow from the Alps[50] contained 0.23–0.63 ng/l for PFOA. The levels found are comparable to other studies that analysed surface snow in the Tibetan mountains[51] and Antarctica.[52]

In some cases, the concentrations for PFOA in snow found in this study are slightly higher than the findings from Greenpeace’s previous study on PFASs in remote locations, where PFOA was detected in samples from Slovakia (0.107 and 0.348 ng/l), Switzerland (0.087 ng/l) and Italy (0.209 ng/l).

In this current investigation PFOS was not detected.

Short-chain PFAS chemicals, including PFBA, were found in five samples .The concentrations of short-chain PFASs detected in this study are comparable with other studies of snow from Antartica.[53]

Finally, this study only looked for one group of persistent chemicals, the PFASs. There are many other hazardous persistent chemical groups, such as brominated flame-retardants, which have been used historically or are still in use today. A small number of the most well known hazardous and persistent chemicals have been banned by the global Stockholm Convention,[54] agreed in 1998. Previous studies have shown other persistent and hazardous chemicals in Antarctica.[55] [56]

The Antarctic Circumpolar Current is known to be a barrier with little connectivity between Antarctic waters and oceanic waters from further north. The oceanic long-range transport of PFASs or other persistent chemicals is thought to be limited.[57]

A much wider investigation would be needed to reveal the full extent of the problem of persistent hazardous chemicals in Antarctica.

Annex 1

Methodology for microfibre samples

Each sample was mixed well by shaking for 20 seconds before decanting a litre of the water into a clean measuring cylinder. This was filtered immediately under vacuum onto a clean silver filter (pore size 5 µm), before being rinsed with filtered deionised water and pentane, dried and inspected under a high power dissecting microscope to identify candidate materials for micro-FT-IR analyses.

For each sample, individual candidate materials (fibres and fragments) retained on the silver filters were examined using a PerkinElmer Spotlight 400 FT-IR Imaging System (MCT detector, KBr window) operating in reflectance mode and with a wavenumber resolution of 4 cm^{-1}. A total of 16 scans were collected for at least two sections of each candidate fibre or fragment, across a wavenumber range from 4000 to 750 cm^{-1}. The infrared spectra were acquired, processed and analysed using PerkinElmer Spectrum software (version 10.5.4.738), with polymers being identified by automated matching combined with expert judgment against commercially available spectral libraries (including polymers, additives, solvents, etc.) and an additional custom spectral library prepared in our laboratory using a range of polymer standards and potential contaminating materials (e.g. tissues, gloves, laboratory coats). Only match qualities greater than 70% were accepted for identification purposes.

Methodology for PFAS samples

Specially pre-cleaned and sealed glass bottles were used for the sampling, which were previously cleaned and heated in the investigation laboratory. All auxiliary items required for sampling were also pre-cleaned, individually wrapped in aluminum foil and transported in PFC-free polyethylene bags.

The samples of snow were taken near the surface with pre-cleaned small stainless steel blades. Two (duplicate) wide mouth 2.5 litre bottles were filled with snow, while attempts were made to compress the snow to achieve the highest possible sample volume. The water samples were filled directly from the shore in two (duplicate) 1 litre glass bottles.

Each duplicate was analysed separately, except for the sample taken in lake II, where bottles were damaged during transport.

For all the snow and water samples, in all locations, field blanks were taken in order to determine if any contamination had occurred during the sampling, or as a result of the equipment used. In each case one 2.5 litre (for snow) or a 1 litre (for water) glass bottle, identical to those used to collect the samples, was transported to and opened at the sampling site and resealed. In the laboratory the bottles were rinsed with purified water which was subsequently analysed in an identical way to the samples.

The closures of all sample bottles were sealed at the sampling site, firstly with a layer of pre-cleaned aluminum foil, a screw cap, and then externally sealed with self-sealing thermoplastic film (parafilm).

Samples were sent to an independent accredited laboratory for analysis.

Annex 2

Details of the analytical results on PFAS

Figure 1: levels of PFASs found in snow samples

Green highlights indicate significant findings. Trace levels of some PFASs were found in field blanks, indicating that concentrations of an equivalent level reported for samples may originate from sources other than the snow or water sample itself, and therefore only significant concentrations are discussed, those being where the concentration is greater than the 2 times above the field blank.

	Blank	Sample	Sample	Blank	Sample	Sample	Blank	Sample	Sample	Blank	Sample	Blank	Sample	Sample
PFAS	S-A.I.1*	S-A.I.2	S-A.I.3	S-A.II.1*	S-A.II.2	S-A.II.3	S-B.I.1*	S-B.I.2	S-B.I.3	S-B.II.1*	S-B.II.3	S-B.III.1*	S-B.III.3+4	S-B.III.5
	Hope Bay Penin-sula	Hope Bay Penin-sula	Hope Bay Penin-sula	Kinnes Cove Joinville Island	Kinnes Cove Joinville Island	Kinnes Cove Joinville Island	Lecointe Kaiser Island	Lecointe Kaiser Island	Lecointe Kaiser Island	Maxwell Bay King George Island	Maxwell Bay King George Island	Discovery Bay Greenwich Island	Discovery Bay Greenwich Island	Discovery Bay Greenwich Island
	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
PFBA	0,067	0,108								**0,13**	**0,325**	**0,1**	**0,468**	**0,181**
PFHxA	0,022	**0,053**	**0,075**	0,022		0,034	0,017	0,027	0,022			**0,029**	**0,047**	**0,081**
PFHpA	0,017		**0,068**				0,013	0,014						
PFOA	0,122	**0,793**	**1,84**	0,12	0,181	0,067	0,025	**0,056**	**0,052**	**0,1**	**1,86**	**0,107**	**0,114**	**0,085**
PFNA	0,017		0,018											
PFDA	0,017		0,021	0,018	0,019	0,019	0,013	0,018	0,014	**0,043**	**0,065**	**0,025**		**0,026**
PFUnA	0,022	0,024	0,026	0,025	0,031	0,029	0,017	0,022	0,021	**0,049**	**0,132**	**0,045**		**0,052**
PFHxS	0,035	0,027	0,029	0,036	0,037	0,032	0,023	0,029	0,028	**0,04**	**0,139**	**0,044**	**0,022**	
∑PFASs	0,319	1,005	2,077	0,221	0,268	**0,181**	0,108	0,166	0,137	0,362	**2,521**	0,35	0,651	0,425

Figure 2: levels of PFASs found in water samples

Green highlights indicate significant findings. Trace levels of some PFASs were found in field blanks, indicating that concentrations of an equivalent level reported for samples may originate from sources other than the snow or water sample itself, and therefore only significant concentrations are discussed, those being where the concentration is greater than the 2 times above the field blank. The seals on two bottles (samples W-A.II.4 and W-B.I.2) were broken during transport prior to sample collection, although all bottles were resealed after sampling. This may not have led to contamination, but it is not certain that this didn't occur; therefore we have excluded results from the analysis of these samples in the discussion above.

	Blank	Sample	Sample	Blank	Sample	Sample	Blank	Sample	Sample
PFAS	W-A.II.1*	W-A.II.2+W-A.II.3	W-A.II.4	W-B.I.1*	W-B.I.2	W-B.I.3+W-B.I.4	W-B.III.1*	W-B.III.3	W-B.III.4
	Kinnes Cove	Kinnes Cove	Kinnes Cove	Lecointe	Lecointe	Lecointe	Discovery Bay	Discovery Bay	Discovery Bay
	Joinville Island	Joinville Island	Joinville Island	Kaiser Island	Kaiser Island	Kaiser Island	Greenwich Island	Greenwich Island	Greenwich Island
	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
PFBA							0,1	0,108	
PFHxA	0,033		0,025	0,04					
PFHpA									
PFOA	0,038	0,05	0,136	0,033	0,125	0,033	0,089	0,12	0,083
PFNA									
PFDA	0,025	0,018	0,077	0,026	0,035	0,014			
PFUnA	0,04	0,032	0,03	0,037	0,035	0,034	0,053	0,048	
PFHxS	0,046	0,05	0,047	0,046	0,046	0,053	0,045	0,038	0,067
∑PFASs	0,182	0,15	0,315	0,182	0,241	0,134	0,287	0,314	0,15

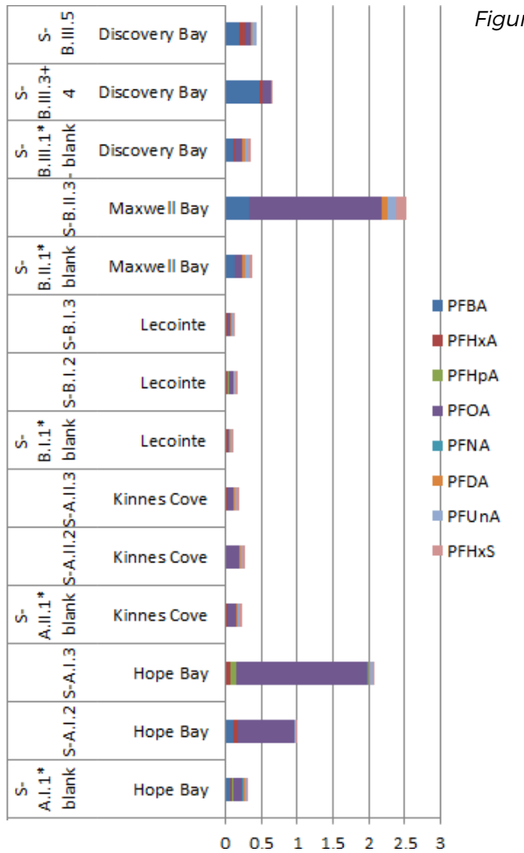


Figure 1: levels of PFASs found in snow samples

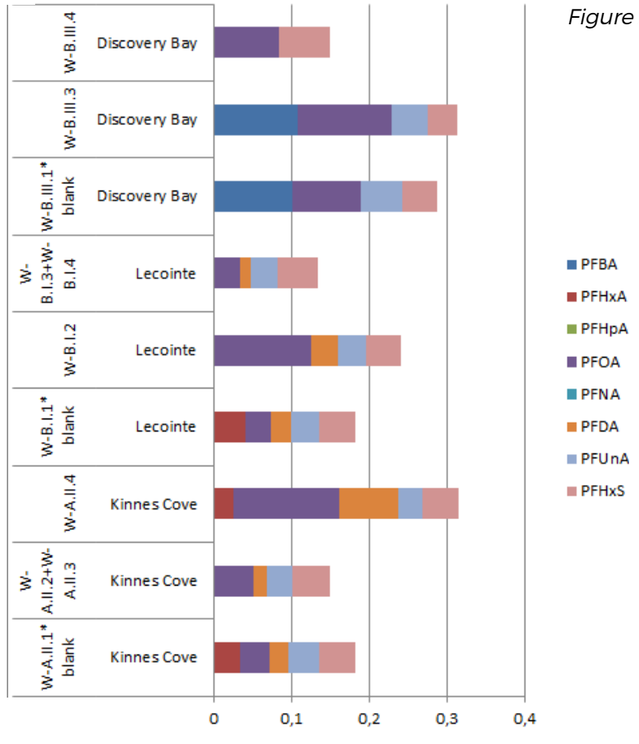


Figure 2: levels of PFASs found in water samples

Annex 3

Details of the manta trawl samples and findings

Figure 3. Antarctic manta trawls 2017 - Arctic Sunrise

5 Gyres net used														
Date	Name	Position	Time start	Time end	Flow start	Flow end	Manta mouth aperture	Fragments found	False contaminates	Marine plastics found	Discrete sample ID	Photo	ATR performed	Sample retained
1/16/2018	18ASA001	S63° 22.741' W56° 56.054'	2055	2135	92600	171700	0.185m x 0.600m	0	0					No
1/19/2018	18ASA002	S63° 23.377' W57° 00.891'	1312	1355	171700	241076	0.185m x 0.600m	0	0					No
2/20/2018	18ASA003	S63° 18.399' W56° 31.251'	1728	1825	241100	339372	0.185m x 0.600m	0	0					No
1/23/2018	18ASA004	S62° 26.079 W59° 03.736	806	906	339372	461979	0.185m x 0.600m	0	0					No
2/27/2018	18ASA005	S64° 30.594' W61° 39.117'	1020	1113	466553	578835	0.185m x 0.600m	1	0	Yes	18ASA005-1	Yes	Polyethylene High Density	Yes
Net Changed to Exeter Manta														
2/16/2018	18ASA006	S64° 49.861' W63° 00.644'	1237	1337	579005	714329	0.155m x 0.870m	15	15					Yes
2/18/2018	18ASA007	S62° 34.451' W59° 45.255'	11.26	12.28	714330	837428	0.155m x 0.870m	8	7	Yes	18ASA007-7	Yes	Polypropylene	Yes
2/19/2018	18ASA008	S62° 25.011' W59° 10.015'	2300	3	837442	957014	0.155m x 0.870m	4	4					Yes
2/28/2018	18ASA009	S62° 41.872' W60° 38.168'	1332	1428	983743	84704	0.155m x 0.870m	1	1					Yes

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A Weddell Seal and Gentoo Penguin
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Endnotes

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Trace levels of some PFASs were found in field blanks, indicating that concentrations of an equivalent level reported for samples may originate from sources other than the snow or water sample itself, and therefore only significant concentrations are discussed, those being where the concentration is greater than the 2 times above the field blank

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The seals on two bottles were broken during transport prior to sample collection, although all bottles were resealed after sampling. This may not have led to contamination, but it is not certain that this didn't occur, therefore we have excluded results from the analysis of these samples in this discussion.

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This finding should be compared with the concentrations in the field blank. For this location the field blank showed 0.361 ng/l for the sum of PFASs.

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PFHxA in field blank detected with 0.029 ng/l

30
PFHxS in field blank detected with 0.04 ng/l

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PFBA in field blank detected with 0.13 ng/l

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